4-1969

Influence of Magnitude of Printing Ink and Printing Pressure on Printing Quality

C. Lee Brandyberry
Western Michigan University

INFLUENCE OF MAGNITUDE OF PRINTING INK AND PRINTING PRESSURE ON PRINTING QUALITY

by

C. Lee Brandyberry

A Thesis submitted to the Faculty
of the Department of Paper Technology
in partial fulfillment of the
Degree of Bachelor of Science

Western Michigan University
Kalamazoo, Michigan
April 19, 1969

ABSTRACT

The purpose of this thesis is to investigate the influence of the magnitude of printing ink and printing pressure on the printing quality of various grades of paper with the ultimate objective of obtaining a standard press setting at which a wide range of papers may be run to determine printing quality. The procedure consisted of printing at various impressions with two different amounts of ink on each grade of paper, measuring the printed samples for ink coverage and printing fidelity to calculate printing quality, and finally, comparing these results to the inherent paper properties. The conclusions drawn show that the degree of printing quality can be rated numerically, thusly eliminating the broad ranges of good, fair, and poor printing quality. In regards to a standard press setting, the printer's methods for which the which the paper is intended should be employed; the level or value of printing quality of the paper should be dictated by the customer's criticisms of the paper's printing quality.

TABLE OF CONTENTS

HISTORICAL BACKGROUND

Introduction

In the past decades, many technical advancements have taken place, both in the manufacturing and printing of paper. Many studies have been made, not only in areas of production volumes, but also in the quality of the finished product. The development of evaluating techniques to measure a paper's printability or printing quality, however, have not kept pace with other developments in the industry (1). This is due to the lack of a suitable definition of printability and printing quality, the lack of effective instrumentation to measure the printing aspects of the sheet, and the complextiy of the printing operation.

Printability is a complex, many faceted subject (2). One authority defines the printability of paper being able to perform satisfactorily on the press; ie., the freedom from defects that cause time loss and and substandard quality in production. The Paper Dictionary defines printability as that property of paper which yields printed material of good quality. Another source defines printability of a surface as the degree to which properties enhance the production of high-quality prints by a particular process.

The matter of definition of terms becomes more confusing and involved when terms such as print quality and runnability are added to the term printability. A distinction must be made between these terms in order to avoid confusion. The term runnability has been used to refer to the paper properties relevant to machinery, while printability is most applicable to stock properties related to the transfer of ink image. Printing quality is best actually used for relating inherent paper properties to the appearance of printed images. Although overlapping of these terms does exist, the combination of the three always focus on three different aspects of paper relevant to printing. These aspects are: (a) that all stocks must be suitable for processing or machining by press equipment, (b) that all stocks must be suitable for transferring the ink image from the printing image carrier, and (c) that the appearance of the final printing image on the stock is influenced by certain paper properties independent of the ink image.

The printing of paper involves three systems which affect the printability, runnability, and printing quality. These are the paper, the ink, and the printing press. Each of these systems is made up of many variables which interrelate in the printing operation. The number of properties possible in each and the influences on one another, all contribute to the complexity of the printing process. With the condition that prevails, obtaining a short, simple evaluation method for determining printing quality has been an objective too far-reaching to accumulate satisfactorally.

Methods of Evaluation

In developing methods of evaluation for printing quality, three views have arisen concerning when the paper variable should be tested. These are: (a) before, (b) after, and (c) both before and after the paper has been printed (1,3). By determining the paper properties before printing, some degree of printing quality can be said to exist, but to even say this, a reference to the final printed sheet must be made initially. By analysis of the results of paper testing data connected with the "appearance" of the printed sheet, some valid conclusions can be drawn to satisfy the measurement of printing quality by the results of the paper testing alone. The ultimate proof of good printing quality, though, lies in examination of the final printed sheet.

In the past there has been a tendency to rely on tests which are indicators of process normality rather than on subjective measurements of the qualities of the outgoing product (4). There are also those tests which indicate the presence of variations or fluctuations in the sheet or product, but which may not be good indicators of variations in the sheet from the printability standpoint. In papermaking, a straightforward, rigorous method of defining end use characteristics and of objectively measuring the printability rate of the paper being produced relative to some set of desired properties is not in operation.

Methods used to determine printing quality of paper on a final printed sample have included the utilization of the proof press using either letterpress or rotogravure processes (1,5,6), the printing gage (7), drawdown methods using a process to simulate printing pressures experienced during the printing operation (8), and microscopic analysis of the printed paper (9). All these methods fall short of the mark of determining printing quality, though, since the methods all lack the necessary, unbiased evaluation of the results obtained. The human aspect is the deterring factor. In the use of proof press methods, a great amount of work has been done to try and alleviate this problem and give reproducible results (5,6).

Other methods concentrate on investigations of the paper's physical properties to determine their influences on the final printability. Of these properties of the sheet, the smoothness seems to be the most important factor for paper to be printed. Other aspects considered to be influential are compressibility, softness, and ink receptivity. These evaluation tests have had partial success in evaluating paper printing quality, but the results obtained lack the ability to correlate with printed paper characteristics of printing quality to the satisfaction of the papermaker and of the printer.

A slightly different approach to measuring printing quality was used by Alex Glasman (10). The method of evaluating the print quality for rotogravure paper was a jury panel, which rated 126 combinations of paper, ink, and presses from best to worst with respect to (a) smoothness of tones, and (b) gloss of inked area. In this study, only a precision roto-press test was able to predict the quality differences with any reliability of the battery of tests considered, including gloss, a letterpress proof press, and Bekk smoothness tests on the sheets.

Multiple correlation coefficients were calculated as a measure of the efficiency of the battery of tests. The correlation is perfect when the multiple correlation coefficient is 1.00. To calculate the coefficients from the data compiled, an IBM 610 computer was used. By taking the square of the coefficient, the variation in printability can be explained to a certain degree. The battery of tests showed that 80 per cent of the variation in printability could be explained by this method. In using just the roto-proof press, 67 per cent of the variation in printability could be explained.

One other interesting fact brought out in this study was that, according to the jury panel rank, the uncoated papers printed more smoothly than the coated papers, although the smoothness tests indicated the coated papers to be more smooth, which would indicate that they should print better. According to another source (11), this result opposes the description of what is taking place on the press and what the smoothness requirements of the paper should be. It is stated that in rotogravure printing, the pressure is mostly acting on the non-printing surfaces. The printing elements, the dots, are depressed below the cylinder surface, making it necessary that the paper surface be smooth at the impression in order that contact is obtained between the paper surface and the ink in the cells.

Many such conflicting results occur in the paper, ink, and press system, making the measurement of printing quality a challenging problem. In order to study the effects of the amount of ink and the pressure applied to the printing quality of the sheet, a method of determining this with the minimum amount of the human aspect must be employed. The standardization and reproducability of the test depends on an unbiased evaluation.

LITERATURE CITED

1. Prior, P.H., Paper Trade Journal 101, No. 15:39-44 (Oct., 1953).

2. Strauss, Victor, "The Printing Industry", 1st ed., New York, Printing Industries of America, 1967, 574-80.

3. Chapman, S.M., Pulp and Paper Magazine of Canada 57, No. 6:144-6 (May, 1956).

4. Holt, S.G., TAPPI 50, No. 6:129A-31A (June, 1967).

5. Zenter, T.G., TAPPI 42, No. 3 (March, 1959).

6. Diehm, R.A., TAPPI 33, No.2:42A, 44A, 46A, 48A (February, 1950).

7. Reed, R.F., TAPPI 38, No. 11:648 (November, 1955).

8. Hull, H.H., and Rogers, M.C., TAPPI 38, No.8:468 (August, 1955).

9. Bekk, J., World's Paper Trade Review, Technical Convention No. 8: 43-52 (March, 1954).

10. Glasman, Alix, TAPPI 44, No. 1:7-11 (January, 1961).

11. Arnamo, Alf, Svensk Papperstidning 66, No. 7:249-55 (April, 1963).

EXPERIMENTAL

Purpose

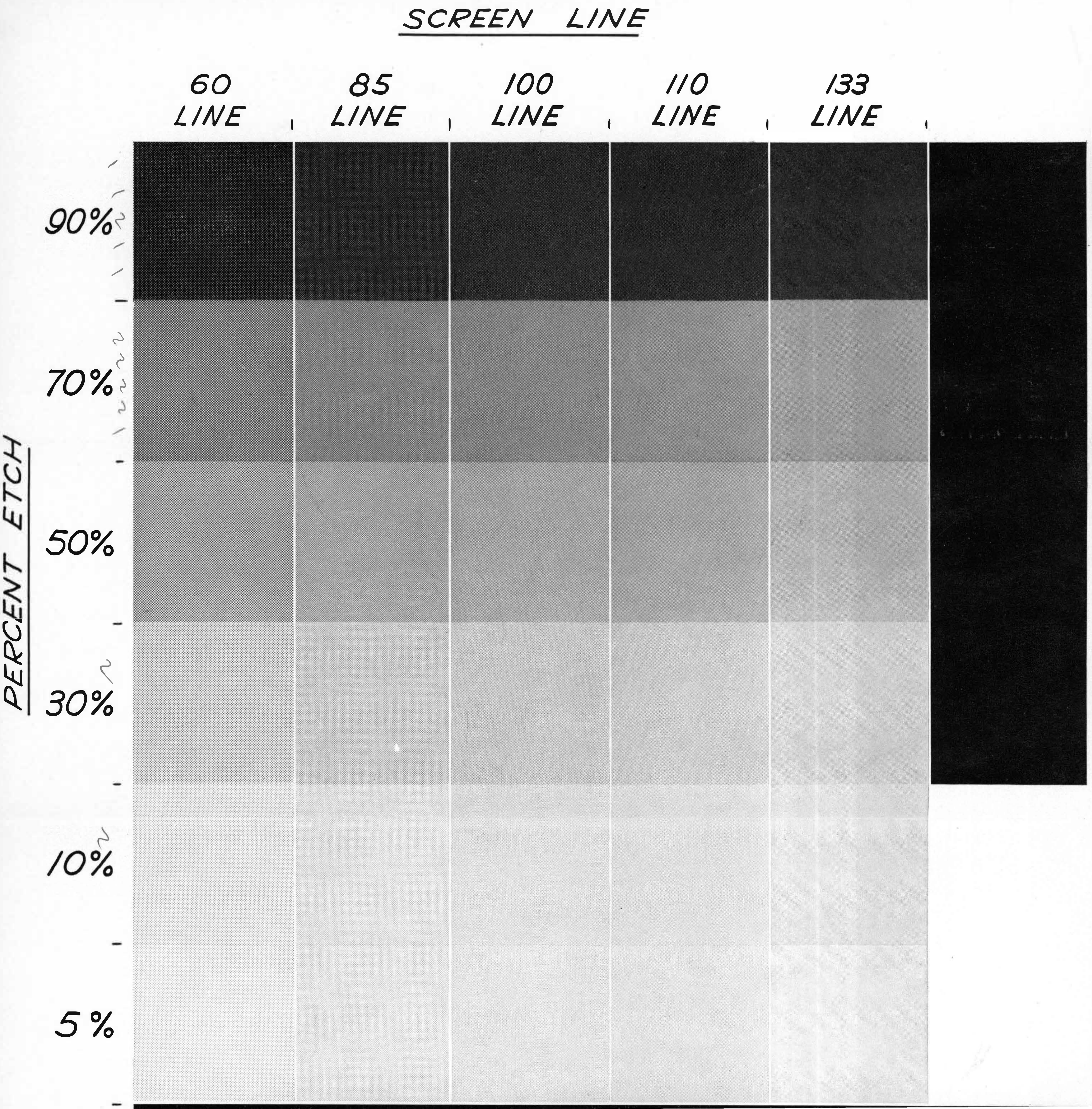
The purpose of this thesis was to study the influence of the magnitude of printing ink and printing pressure on the printing quality of paper. As stated in the introduction, the main problem encountered is finding a method which is as unbias as possible, as well as, reproducable. The following method was used to cope with the entire problem and to find the results obtained.

General Design

The apparatus used to print the various paper samples was a Vandercook Universal I proof press. The plate used was made up of halftone screens ranging from 60 line, as used for newsprint, to 133 line, which is used in the printing of fine papers for magazines, etc. The various screen sizes include 60, 85, 100, 110, and 133 line which are side by side, horizontally, across the width of the plate. Different tones, or etch, varying from a highlight to a solid, including strips of 10, 30, 50, 70, and 90 per cent etch, are arranged in a vertical sequence the length of the plate (See Figure 1).

The final print of each sample was evaluated for printing quality by using a combination or product of two factors: (a) ink coverage, and (b) printing fidelity.

The ink coverage is determined by the average brightnesses of the 10 per cent tone, the 90 per cent tone, and the unprinted paper. The ink coverage (I.C.) is calculated by the formula following:


SCREEN LINE
60 LINE
85 LINE
100 LINE
110 LINE
133 LINE
PERCENT ETCH
90%
70%
50%
30%
10%
5%

$$I.C. = \frac{B10 - B90}{B.P.}$$

where B10 - the average brightness of the 10 per cent tones.
B90 - the average brightness of the 90 per cent tones.
B.P.- the brightness of the paper.

The perfect print will have an ink coverage of 80 per cent; ie., the difference between perfect 10 per cent and 90 per cent tones.

The second factor to be evaluated for printing quality determination was printing fidelity since the screen pattern was also vitally important. This was done by means of a hand lens. The 10, 30, 70, and 90 per cent tones for each of the five different screen sizes was evaluated for the absence of dots. A perfect tone was given the value of two. With only a few dots missing, a value of one was given, while when more than 20 per cent of the dots were missing, the value was zero. With only three values possible of being assigned to each tone mentioned of each screen size, the probalility of reproducability was high. With a greater number of values possible, the variation from observer to observer would be much greater. Therefore, for perfect printing fidelity, each tone has a value of two and the entire print has a value of 40 (value of 2 times 4 different tones times 5 screen sizes).

The calculation of printing quality, expressed as the ink coverage obtainable with perfect printing fidelity, is found numerically by:

$$P.Q. = \frac{I.C. \times P.F.}{32}$$

The denominator is a constant calculated by finding the product of the perfect ink coverage (0.80) and the perfect printing fidelity (40). By this method of evaluation the perfect printing quality will be 1.00.

The Vandercook proof press used is equipped with an ink monitor which measures the amount of ink on the ink roller system by means of a photocell. The measurement is only relative and not specific. A filter standardizes the read out on the gage before make-ready, then the ink may be added to the ink fountain and distributed to the ink rollers until a certain value on the monitor is reached. A transfer lag time of one minute was used to insure proper distribution in applying or reapplying ink from the ink fountain roller to the rest of the ink rolls. Two different settings were used on the ink monitor to obtain prints on each sample or grade of paper, 4.5 and 5.0. The ink used was a letterpress non-drying proofing black (#5 tack) made by I.P.I.

The printing pressures, at which each sample was printed, was determined by the height of the bed on which the plate rests. First, a zero impression point was found by placing the sample sheet over the plate, and then positioning the impression cylinder directly above the paper and plate. The height of the bed was regulated by a crank, found at the foot of the bed, until the paper sample just barely slides, or can just barely be pulled between the nip formed by the plate and the impression cylinder. The crank can then be positioned for the pressure wanted since it is calibrated in thousandths of an inch. For example, after the zero impression for each sample has been found, the procedure is simply to raise the bed, by use of the crank, the desired number of units (thousandths of an inch) for printing the sample. Therefore, a plus-two impression (plus-two Imp.) means that the bed, and furthermore, the plate, have been raised two thousandths of an inch over the zero impression. The impression cylinder is fixed in position and, thusly, a greater pressure is exerted between the plate and the cylinder.

Each grade of paper was printed at plus 2, 5, 8, and 6 on respective sheets, first at a 4.5 ink level and then repeated again at the 5.0 ink level. Between ink level changes and sample or grade of paper changes. the plate was completely cleaned. The plate is inked or re-inked prior to printing another set by allowing the ink rolls to make two passes (down and back) over the plate at the 4.5 ink level and a standard pressure setting. When this was being done, the impression cylinder is raised by a lever in order that it will not contact the plate. The speed of cylinder travel was constant throughout the operation, at its lowest linear speed.

Paper property tests were run on each grade of paper also. The Bekk smoothness test was run according to the procedure recorded in TAPPI standard T-479sm-48 with the following changes:

(a) The smoothness is taken only on the felt side of the sample.
(b) The smoothness determinations were made covering the majority of the test sample. The average value is determined and recorded.
(c) The 1/10 position was used when the smoothness was over 2 minutes or 120 seconds long. The result was then multiplied by ten to convert it to a zero position reading.

A measure of the ink receptivity of each grade was accomplished by K and N ink measurement. This procedure is, briefly, finding the loss in brightness associated with a paper sample when an excess of K and N ink is applied to the sheet, allowed to set for two minutes, and is then wiped off. The loss in brightness found is directly proportional to the ink receptivity.

The density of each sheet was also found since it gives a measurement of compressibility, which is important in printing papers. The density was calculated by finding the product of the sheet's basis weight and the reciprocal of its caliper and then applying a conversion factor.

The basis weight of each sheet was found by weighing a die-cut disk and then multiplying this weight by a conversion factor. The caliper was found by the use of a constant loading, caliper apparatus made by Testing Machines, Inc.

PRESENTATION OF RESULTS

Table I shows the results of the ink coverage, the printing fidelity, and the calculated printing quality for each of the grades of paper, the two different ink settings, and the four different pressures employed.

Table II gives the average printing quality for the 5, 6, and 8 impression pressures. The plus-two impression is omitted from this average since in the majority of the samples printed at this pressure, the printing fidelity was found to be zero, making the printing quality zero. With the values being the same for a majority of the samples, very little information can be subjected to conclusion.

In this second table, the average printing quality is ranked in order, from highest to lowest. The same is done for each of the values at each pressure. The deviations from the average printing quality rank are noted for each different pressure. As can be seen, this is done in two ways: (a) considering the two different amounts of ink and their effect on each sample, separately, and (b) averaging the two amounts of ink for each grade of paper.

In Table III, the paper properties of smoothness, density (in grams per cubic centimeter), basis weight (pounds per 25 x 38-500), and ink receptivity are contrasted with the average printing quality and the printing quality obtained with a plus-six impression pressure.

The relationship between both smoothness and average printing quality and smoothness and the printing quality for the plus - six impression is shown in Figures 1 and 2. The theoretical line is an assumption of what these graphs should look like if the relation, as the smoothness increases, the printing quality increases, holds true to form.

TABLE I. Ink Coverage, Printing Fidelity, and Printing Quality Results

GRADE/ PAPER	I.C. 2	I.C. 5	I.C. 6	I.C. 8	P.F. 2	P.F. 5	P.F. 6	P.F. 8	P.Q. 2	P.Q. 5	P.Q. 6	P.Q. 8
4.5 Ink												
#4	.702	.783	.782	.755	13	32	36	38	.285	.783	.880	.897
STD.	.544	.776	.760	.753	4	29	30	36	.068	.703	.713	.847
#11	.454	.732	.731	.720	1	18	25	36	.014	.412	.571	.810
#6	.443	.734	.718	.736	0	14	21	34	.000	.321	.471	.782
#13	.543	.722	.724	.723	0	9	21	27	.000	.203	.475	.610
#10	.622	.592	.575	.566	0	16	19	23	.000	.296	.341	.407
#15	.613	.613	.612	.586	0	13	18	22	.000	.249	.344	.403
#7	.627	.650	.632	.608	0	12	14	21	.000	.244	.277	.399
#3	.550	.590	.604	.596	0	11	16	19	.000	.203	.302	.354
#8	.327	.523	.499	.537	0	3	7	20	.000	.049	.109	.366
#2	.286	.483	.485	.550	0	6	7	17	.000	.097	.106	.292
AVE.	.519	.654	.647	.648	1.6	15	20	27	.033	.324	.417	.570
5.0 Ink												
#4	.777	.790	.792	.765	11	33	37	38	.267	.815	.916	.908
STD.	.634	.786	.772	.757	8	26	31	36	.159	.639	.748	.852
#11	.474	.767	.756	.746	0	22	28	38	.000	.527	.662	.886
#6	.473	.752	.762	.752	0	15	23	38	.000	.353	.348	.893
#13	.561	.742	.748	.750	0	17	24	30	.000	.394	.561	.703
#10	.590	.594	.612	.679	2	18	20	32	.039	.334	.383	.602
#15	.639	.639	.612	.579	3	19	23	27	.060	.379	.440	.489
#7	.664	.659	.637	.590	0	16	19	31	.000	.330	.378	.572
#3	.589	.639	.605	.609	0	10	14	18	.000	.200	.265	.343
#8	.370	.544	.563	.576	0	8	14	24	.000	.136	.246	.432
#2	.307	.518	.517	.559	0	7	10	18	.000	.113	.162	.314
AVE.	.553	.675	.651	.662	2.2	17	22	30	.093	.384	.483	.636

TABLE II. Deviations of Individual Printing Quality from the Average Printing Quality

GRADE/ PAPER(Ink)	AVE. P.Q.	P.Q. VALUES 5	6	8	RANKS PQ	5	6	8	DEV. FROM AVE. P.Q. 5	6	8
#4 (5.0)	.913	.815	.916	.908	1	1	1	1	0	0	0
STD. (4.5)	.821	.703	.913	.847	2	3	2	6	1	0	4
#4 (4.5)	.753	.783	.880	.897	3	2	3	2	1	0	1
STD. (5.0)	.746	.639	.748	.852	4	4	4	5	0	0	1
#11 (5.0)	.692	.527	.662	.886	5	5	5	4	0	0	1
#6 (5.0)	.598	.353	.548	.893	6	9	8	3	3	2	3
#11 (4.5)	.598	.412	.571	.810	7	6	6	7	1	1	0
#13 (5.0)	.553	.394	.561	.703	8	7	7	9	1	1	1
#6 (4.5)	.525	.321	.471	.782	9	12	10	8	3	1	1
#10 (5.0)	.440	.334	.383	.602	10	10	12	11	0	2	1
#15 (5.0)	.436	.379	.440	.489	11	8	11	13	3	0	2
#13 (4.5)	.429	.203	.475	.610	12	16	9	10	4	3	2
#7 (5.0)	.427	.330	.378	.572	13	11	13	12	2	0	1
#10 (4.5)	.348	.296	.341	.407	14	13	15	15	1	1	1
#15 (4.5)	.332	.249	.344	.403	15	14	14	16	1	1	1
#7 (4.5)	.307	.244	.277	.399	16	15	17	17	1	1	1
#3 (4.5)	.286	.203	.302	.354	17	17	16	19	0	1	2
#8 (5.0)	.271	.136	.246	.432	18	19	19	14	1	1	4
#3 (5.0)	.269	.200	.265	.343	19	18	18	20	1	1	1
#2 (5.0)	.196	.113	.162	.314	20	20	20	21	0	0	1
#8 (4.5)	.175	.049	.109	.366	21	22	21	18	1	0	3
#2 (4.5)	.163	.091	.106	.292	22	21	22	22	1	0	0
Totals on the Deviations--									26	16	32

#4	.833	.799	.898	.903	1	1	1	1	0	0	0
STD.	.784	.671	.831	.850	2	2	2	2	0	0	0
#11	.645	.470	.617	.848	3	3	3	3	0	0	0
#6	.563	.337	.510	.838	4	4	5	4	0	1	0
#13	.491	.299	.518	.657	5	7	4	5	2	1	0
#10	.394	.315	.362	.505	6	5	7	6	1	1	0
#15	.384	.314	.392	.446	7	6	6	8	1	1	1
#7	.367	.287	.328	.486	8	8	8	7	0	0	1
#3	.278	.202	.284	.349	9	9	9	10	0	0	1
#8	.223	.093	.178	.399	10	11	10	9	1	0	1
#2	.130	.101	.134	.303	11	10	11	11	1	0	0
Totals on the Deviations--									6	4	4

TABLE III. Smoothness, Density, Basis Weight, and Ink Receptivity Contrasted with Printing Quality

GRADE/ PAPER	AVE. P.Q.	6 IMP.	SMOOTH- NESS	DEN- SITY	BASIS WEIGHT	INK RECEP.
#4	.833	.898	403.	1.063	107.6	39.0
STD.	.784	.831	622.	1.191	69.9	27.7
#11	.645	.617	72.6	1.015	79.8	28.5
#6	.563	.510	76.3	1.008	96.9	33.8
#13	.491	.518	19.9	1.031	68.5	49.4
#10	.394	.362	48.4	.776	61.3	50.6
#15	.384	.392	58.0	.760	48.0	49.5
#7	.367	.328	58.2	.785	71.1	49.7
#3	.278	.284	35.0	.763	78.6	54.1
#8	.223	.178	14.2	..601	50.0	49.6
#2	.130	.134	10.2	.603	62.1	51.6

Figure 1. Smoothness vs. Average Printing Quality and Printing Quality for Plus-6 Impression

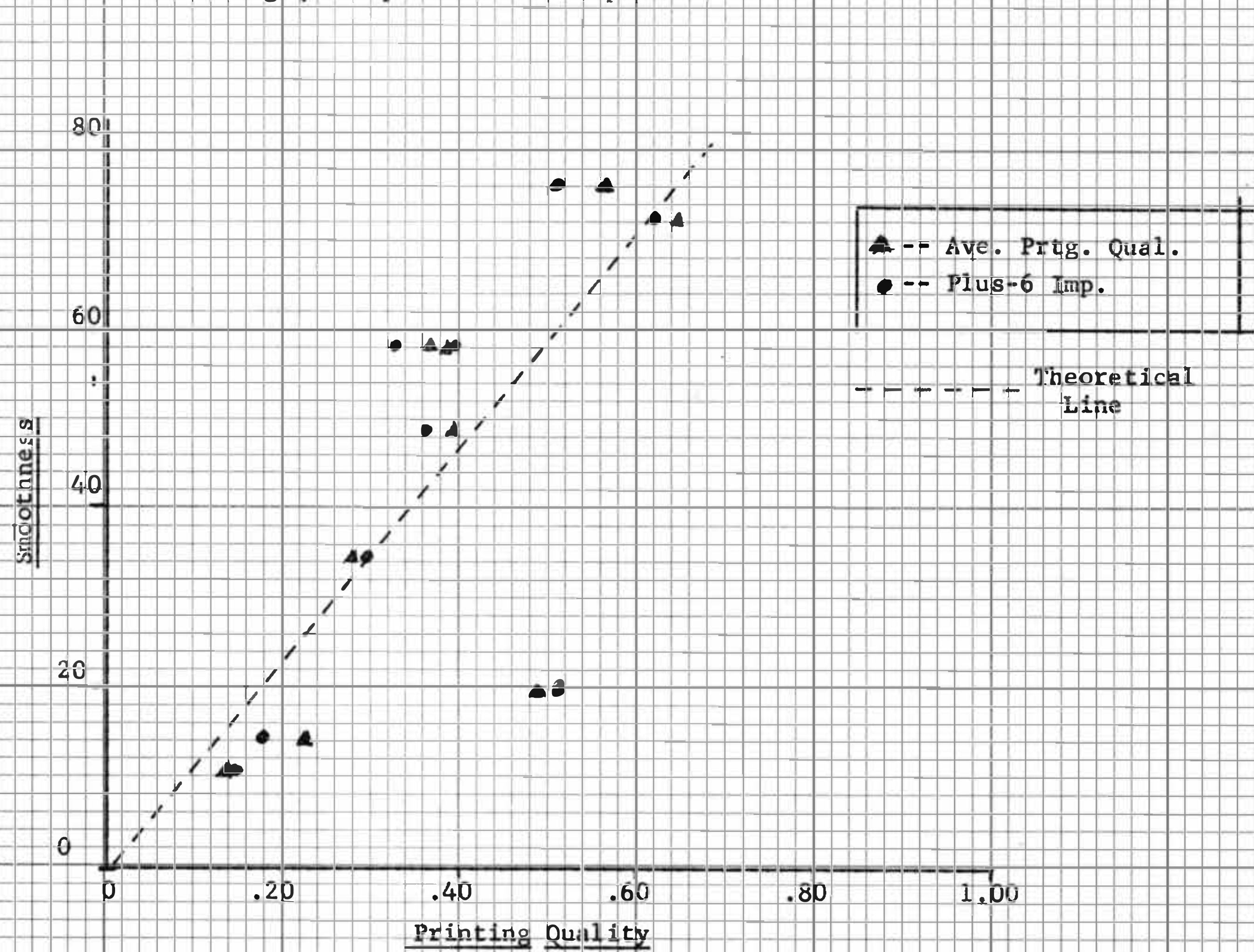
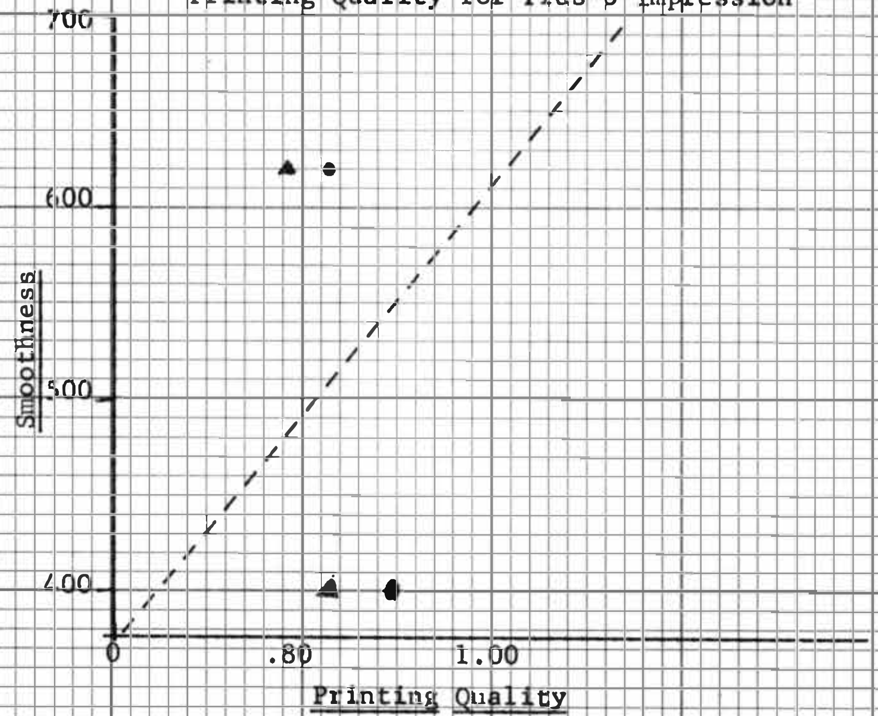


Figure 2. Smoothness vs. Average Printing Quality and Printing Quality for Plus-6 Impression



Discussion of Results

From the results obtained, shown in Table I, the relatioships between the magnitude of printing ink and printing pressures used reflect on the printing quality calculated from ink coverage and printing fidelity of each sample. The average values for all the samples best show these relationships. The first thing that can be seen is that the greater the amount of ink applied to the sheet, the better the printing quality. This is logical up to a certain amount of ink. At any pressure, by increasing the ink supplied to the ink rollers, the ink coverage increases as well as the printing fidelity since a greater number of dots on the plate will be inked and therefore, present on the printed sample. A second observation pertains to the effect on printing quality with increased printing pressures. As can be noted, the printing quality increases as the printing pressures are increased up to the eight thousandths of an inch impression. This phenomenon is due substantually to the increase in the presence of dots; ie., the printing fidelity. This was also expected and logically deduced since the sheet was placed under a higher pressure and thusly, more of the raised surfaces on the plate came in contact with the sheet. Why the ink coverage drops off under higher pressure is not known.

In Table II, the plus-six impression deviates the least from the average printing quality of the three pressures considered. This points out that this one pressure may be used singularly to give the best estimate of the printing quality as determined by using the average of the printing qualities found for three different pressures. In other words, if one standard pressure was to be decided upon, to determine printing quality, although actually, using the average value of three different printing qualities from three different press pressures gives the best indication (specifically, the 5, 6, and 8 thousandths of an inch impression), the plus-six impression would be chosen. In regards to the magnitude of ink that should be used, it should be kept at a minimum to defray expense and adhere to the principles of the printer without sacrificing a range of printing fidelity values for the various printing pressures or having too low a printing fidelity value.

The results noted in Table III bring out many interesting, as well as puzzling, correlations. The smoothness shows a trend of being related with the printing quality of the printed sheet with one possible exception (Sample 13) which has a low smoothness (9th in rank) but a fairly high printing quality when compared to the others (5th). This must mean that this sample has some other property which attributes to its final printing quality. At first glance, the ink receptivity seems to be this property, since the value for Sample 13 is higher than those for the samples with higher printing quality, but there are samples with lower printing qualities with both higher smoothnesses and higher ink receptivities than this grade of paper. Some other factor must be considered. The density, in comparison with the basis weight, is a measure of the compressibility of the sheet. The greater the compressibility of the sheet, the better the printing quality of the sheet. This might be a positive factor when comparing this sample with the rest of the samples. Assuming that the printing qualities obtained are correct, this shows that more than just one or two variables or paper properties are guidelines to printing quality evaluations.

CONCLUSIONS

Under the evidence of this thesis, both the magnitude of ink and the printing pressure were found to have a direct bearing on the final printing quality of the sheet. If either one, or both, are increased slightly, the printing quality of the printed paper increases.

Finding a standardized setting for the amount of ink and the pressure for determining printing quality, depends on the customer's printing methods and the printed sheet's end use. The ultimate end use test would be to print all the paper in a manner equivalent to that used by the customer. This is impractical and, thus, a standard press setting, closely adhering to what a printer or customer would like to run at, should be adopted. When such a standard is adopted, the testing can show variances in a grade being produced, comparisons with the competitor's papers, save time, and money. The problems of sampling and simulating the customer's printing operation have limited value of such determinations. The trend is toward the measurements of individual printability factors, paper properties, and process variables, with proof-printing as a rough overall test.